SGM42613
Dual H-Bridge Motor Controller IC

GENERAL DESCRIPTION

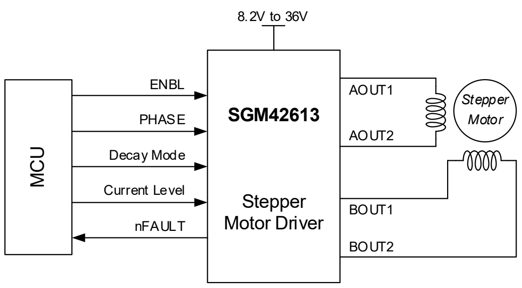
The SGM42613 is a motor driver device with two integrated H-bridges that can run a bipolar stepper motor. It can be used in a variety of applications from printers and scanners to factory automation and robotics. Each H-bridge consists of four N-MOSFETs to drive one motor winding. With proper heatsinking, each H-bridge can deliver up to 2.5A (at V_M = 24V, T_J = +25℃).

This device uses an industry standard parallel digital interface. The output full-scale current can be scaled in four levels (0%, 38%, 71% and 100%). The decay mode (slow, fast, or mixed) can be selected by DECAY pin. Sleep mode allows saving power when the device is not driving the motor.

Protection features include over-current, short-circuit, under-voltage lockout and thermal shutdown. Upon detecting such events, the device will shut down.

The SGM42613 is available in a Green TSSOP-28 (Exposed Pad) package.

SIMPLIFIED SCHEMATIC



FEATURES

- **8.2V to 36V Operating Voltage Range**
- **Up to 2.5A Drive Current at V_M = 24V, T_J = +25℃**
- **Dual H-Bridge Current Controlled Motor Driver**
- **Drives a Bipolar Stepper Motor**
- **Four Current Scaling Control**
- **Selectable Slow, Fast or Mixed Decay Modes**
- **Industry Standard Parallel Digital Interface**
- **Low Current Sleep Mode**
- **3.3V Reference Output**
- **Full Set of Protections**
  - **Over-Current Protection (OCP)**
  - **Thermal Shutdown (TSD)**
  - **V_M Under-Voltage Lockout (UVLO)**
  - **Active Low Fault Indication Pin (nFAULT)**
- **Available in a Green TSSOP-28 (Exposed Pad) Package**

APPLICATIONS

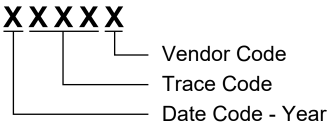
Money Handling Machines
ATM
Printers
Scanners
Office Automation Equipment
Robotics
Gaming Machines

PACKAGE/ORDERING INFORMATION

MODEL	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM42613	TSSOP-28 (Exposed Pad)	-40℃ to +125℃	SGM42613XPTS28G/TR	SGM42613 XPTS28 XXXXX	Tape and Reel, 4000

MARKING INFORMATION

NOTE: XXXXX = Date Code, Trace Code and Vendor Code.



Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

ABSOLUTE MAXIMUM RATINGS

Power Supply Voltage Range, V_M .... -0.3V to 38V
Power Supply Slew Rate 1V/μs
Digital Pins Voltage Range .... -0.5V to 6V
xVREF Input Voltage Range, V_{REF} .... -0.3V to 4V
ISENx Pins Voltage Range .... -0.8V to 0.8V
Peak Output Current, (t < 1μs) .... Internally Limited
Motor Drive Output Current .... 0A to 2.5A
Package Thermal Resistance
  TSSOP-28 (Exposed Pad), θ_{JA} .... 29℃/W
  TSSOP-28 (Exposed Pad), θ_{JC} .... 14℃/W
Package Thermal Characterization Parameter
  TSSOP-28 (Exposed Pad), ψ_{JT} .... 0.75℃/W
Junction Temperature .... +150℃
Storage Temperature Range .... -65℃ to +150℃
Lead Temperature (Soldering, 10s) .... +260℃
ESD Susceptibility
HBM 4000V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Power Supply Voltage Range, V_M .... 8.2V to 36V
xVREF Input Voltage Range, V_{REF} .... 1V to 3.5V
Continuous Motor Drive Output Current .... 0A to 2A
V3P3OUT Load Current, I_{V3P3} 1mA
Operating Ambient Temperature Range ...... -40℃ to +125℃
Operating Junction Temperature Range ...... -40℃ to +150℃

OVERSTRESS CAUTION

Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Functional operation of the device at any conditions beyond those indicated in the Recommended Operating Conditions section is not implied.

DISCLAIMER

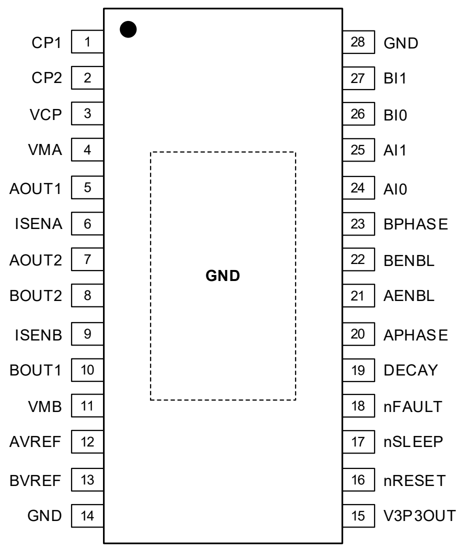
SG Micro Corp reserves the right to make any change in circuit design, or specifications without prior notice.

ESD SENSITIVITY CAUTION

This integrated circuit can be damaged if ESD protections are not considered carefully. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because even small parametric changes could cause the device not to meet the published specifications.

PIN CONFIGURATION

(TOP VIEW)



TSSOP-28 (Exposed Pad)

PIN DESCRIPTION

PIN	NAME	TYPE	DESCRIPTION	
1	CP1	I/O	Charge Pump Flying Capacitor Connection Pins. Connect a 0.01μF/50V capacitor between CP1 and CP2. This capacitor generates gate drive voltage for the high-side internal power N-MOSFETs of the H-bridges.	
2	CP2	I/O		
14, 28	GND	-	Device Ground.	
3	VCP	I/O	High-side Gate Drive Voltage. Connect a 0.1μF/16V ceramic capacitor between this pin and VM.	
4	VMA	-	Power Supply for Bridge A.	Connect these pins to the same motor supply (8.2V to 36V) and bypass each with a 0.1μF ceramic capacitor to GND. Connect sufficient bulk capacitance to the common supply line.
11	VMB	-	Power Supply for Bridge B.	
15	V3P3OUT	O	3.3V Regulator Output. Bypass to GND with a 1μF/6.3V ceramic capacitor. This source can be used to supply AVREF or BVREF reference inputs.	
21	AENBL	I	Enable Input for Bridge A. Logic high on this pin enables bridge A.	
20	APHASE	I	Bridge A Phase (Direction) Input. Logic high sets AOUT1 high and AOUT2 low.	
24	AI0	I	Bridge A Current Scale Factor Setting. Use these 2 logic inputs to set bridge A scale factor: 00 = 100%, 01 = 71%, 10 = 38%, 11 = 0% (Disabled output).	
25	AI1	I		
12	AVREF	I	Bridge A Current Setting Reference Voltage Input. It can be driven independently with a DAC for microstepping, or tied to a fixed reference like V3P3OUT. Using a 0.01μF bypass capacitor to GND is recommended.	
22	BENBL	I	Enable Input for Bridge B. Logic high on this pin enables bridge B.	
26	BI0	I	Bridge B Current Scale Factor Setting. Use these 2 logic inputs to set bridge B scale factor: 00 = 100%, 01 = 71%, 10 = 38%, 11 = 0% (Disabled output).	
27	BI1	I		
23	BPHASE	I	Bridge B Phase (Direction) Input. Logic high sets BOUT1 high and BOUT2 low.	
13	BVREF	I	Bridge B Current Setting Reference Voltage Input. It can be driven independently with a DAC for microstepping or tied to a fixed reference like V3P3OUT. Using a 0.01μF bypass capacitor to GND is recommended.	
19	DECAY	I	Decay Mode Selection Input. Low = slow decay, open = mixed decay, high = fast decay.	
16	nRESET	I	Active-Low Reset Input. Initialize internal logic and disable the H-bridge outputs.	
17	nSLEEP	I	Active-Low Sleep Mode Input. Apply high to enable device, and low to enter in the low-power sleep mode.	
18	nFAULT	OD	Active-Low Fault Flag. Go low when a fault occurs (over-temperature, over-current).	
5	AOUT1	O	Bridge A Output 1.	Connect to motor winding A terminals 1 and 2 respectively.
7	AOUT2	O	Bridge A Output 2.	
10	BOUT1	O	Bridge B Output 1.	Connect to motor winding B terminals 1 and 2 respectively.
8	BOUT2	O	Bridge B Output 2.	
6	ISENA	I/O	Bridge A I_{SENSE} (GND). Connect through a current sense resistor to GND for bridge A.	
9	ISENB	I/O	Bridge B I_{SENSE} (GND). Connect through a current sense resistor to GND for bridge B.	
Exposed Pad	GND	G	Ground.	

NOTE: Directions: I = input, O = output, OD = open-drain output, I/O = input/output, G = ground.

ELECTRICAL CHARACTERISTICS

(T_J = +25℃, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supplies						
VM Operating Supply Current	I_{VM}	V_M = 24V		2	3	mA
VM Sleep Mode Supply Current	I_{VMQ}	V_M = 24V		0.005	2	μA
VM Under-Voltage Lockout Threshold	V_{UVLO}	V_M rising		7.7	8.2	V
V3P3OUT Regulator						
V3P3OUT Voltage	V_{3P3}	I_{OUT} = 0mA to 1mA, V_M = 24V, T_J = +25℃	3.20	3.30	3.48	V
		I_{OUT} = 0mA to 1mA, T_J = -40℃ to +125℃	3.17	3.30	3.51	
Logic-Level Inputs						
Input Low Voltage	V_{IL}	T_J = -40℃ to +125℃		0.6	0.7	V
Input High Voltage	V_{IH}	T_J = -40℃ to +125℃	2.6		5.5	V
Input Hysteresis	V_{HYS}			1.3		V
Input Low Current	I_{IL}	V_{IN} = 0mA	-20		20	μA
Input High Current	I_{IH}	V_{IN} = 3.3V			100	μA
Sleep Input						
Input Low Threshold Voltage	V_{IL}	T_J = +25℃		0.65		V
		T_J = -40℃ to +125℃			0.35	V
Input High Threshold Voltage	V_{IH}	T_J = -40℃ to +125℃	2.5			V
Input Hysteresis	V_{HYS}			1.1		V
nFAULT Output (Open-Drain Output)						
Output Low Voltage	V_{OL}	I_{OUT} = 5mA			0.5	V
Output High Leakage Current	I_{OH}	V_{OUT} = 3.3V			1	μA
Decay Input						
Input Low Threshold Voltage	V_{IL}	For slow decay mode		1		V
Input High Threshold Voltage	V_{IH}	For fast decay mode		2.3		V
Input Current	I_{IN}		-40		40	μA
H-Bridge FETs						
HS FET On-Resistance	R_{DSON}	V_M = 24V, I_{OUT} = 1A, T_J = +25℃		0.27		Ω
		V_M = 24V, I_{OUT} = 1A, T_J = +85℃		0.37	0.5	
LS FET On-Resistance		V_M = 24V, I_{OUT} = 1A, T_J = +25℃		0.22		
		V_M = 24V, I_{OUT} = 1A, T_J = +85℃		0.30	0.35	
Motor Driver						
Current Sense Blanking Time	t_{BLANK}			2.8		μs
Rise Time	t_R	V_M = 24V	30		150	ns
Fall Time	t_F	V_M = 24V	25		140	ns
Dead Time	t_{DEAD}			400		ns
Input Deglitch Time	t_{DEG}			2		μs
Protection Circuits						
Over-Current Protection Trip Level	I_{OCP}			3		A
Thermal Shutdown Temperature	T_{SD}	Die temperature		155		℃
Current Control						
xVREF Input Current	I_{REF}	V_{REF} = 3.5V	-3		3	μA
ISENx Trip Voltage	V_{TRIP}	V_{REF} = 3.3V, 100% current setting	635	661	685	mV
		V_{REF} = 3.3V, 71% current setting	445	468	492	
		V_{REF} = 3.3V, 38% current setting	225	251	276	
Current Sense Amplifier Gain	A_V	Reference only		5		V/V

FUNCTIONAL BLOCK DIAGRAM

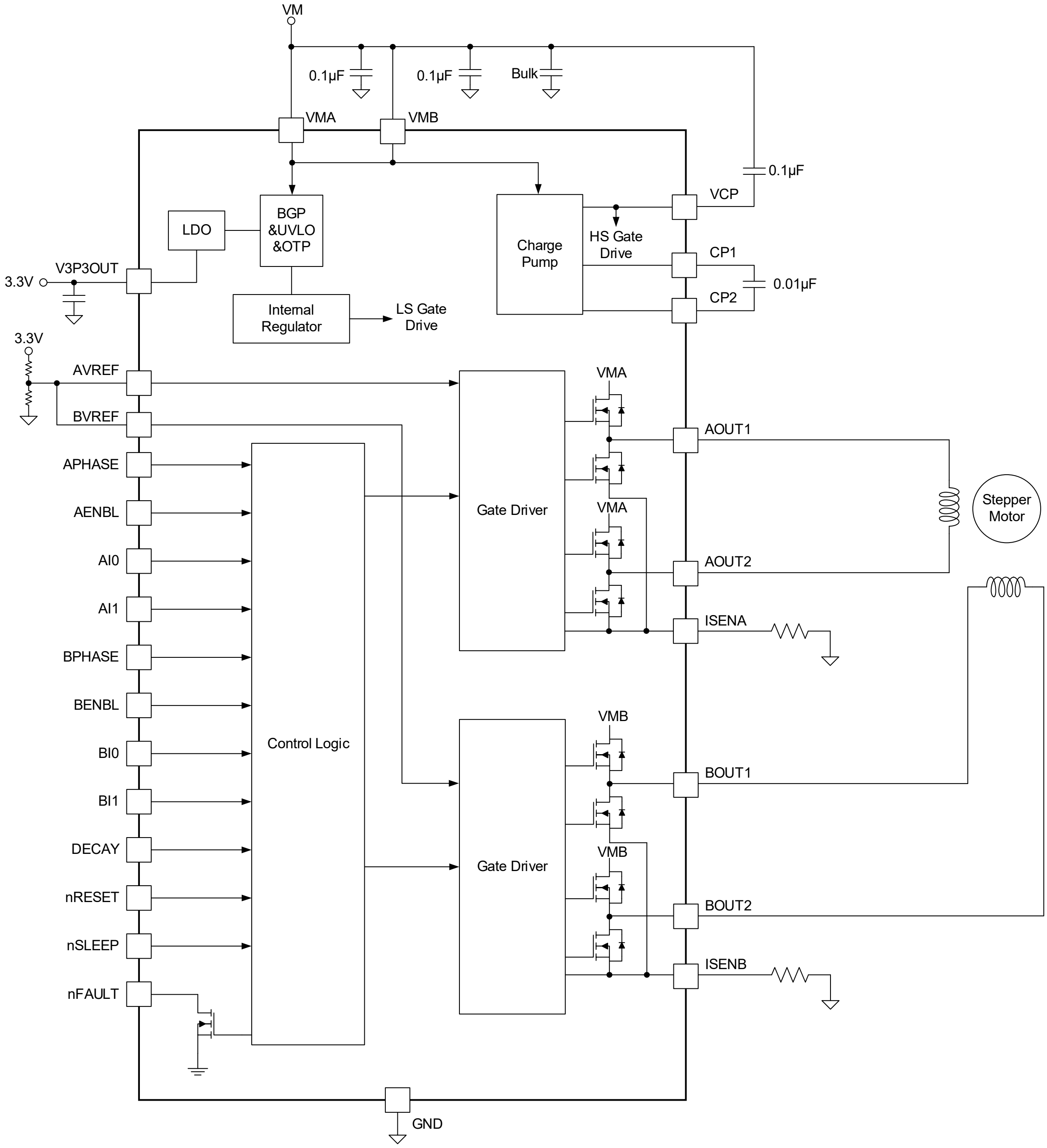
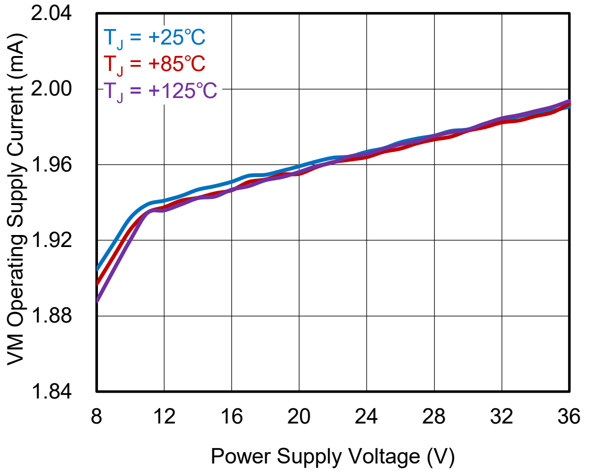


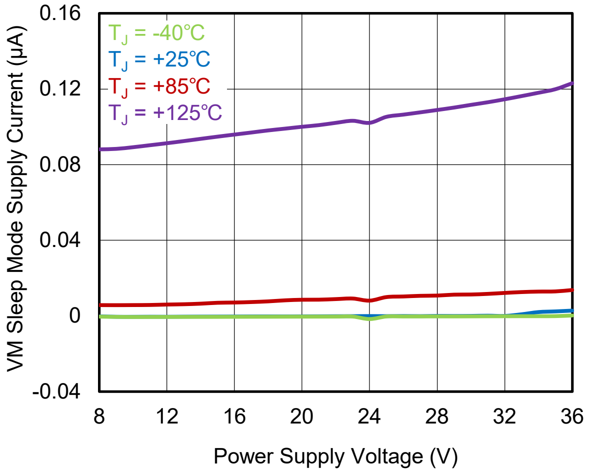
Figure 1. SGM42613 Block Diagram for Stepper Motor Driving

TYPICAL PERFORMANCE CHARACTERISTICS

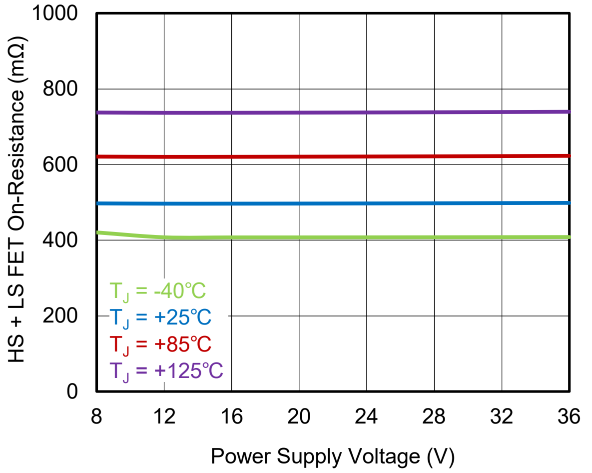
VM Operating Supply Current vs. Power Supply Voltage



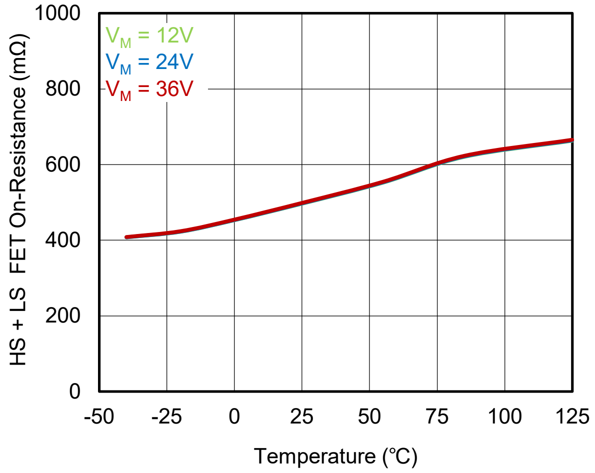
VM Sleep Mode Supply Current vs. Power Supply Voltage



HS + LS FET On-Resistance vs. Power Supply Voltage



HS + LS FET On-Resistance vs. Temperature



DETAILED DESCRIPTION

Overview

The SGM42613 can drive a bipolar stepper motor. This device includes two integrated N-MOSFET H-bridges with current sense. The control, regulation circuits and comprehensive fault detection features are also included. It can operate with supply voltages from 8.2V to 36V, and deliver full-scale current up to 2.5A.

The external controller can be linked with a simple xPHASE and xENBL interface. The winding currents can be regulate with selectable, slow, fast and mixed decay modes that are chosen based on the application needs.

Sleep mode allows saving power when the motor is not driven.

PWM Motor Drivers

Figure 2 shows the block diagram of the SGM42613 with PWM motor control circuits including two H-bridges driving a bipolar stepper motor.

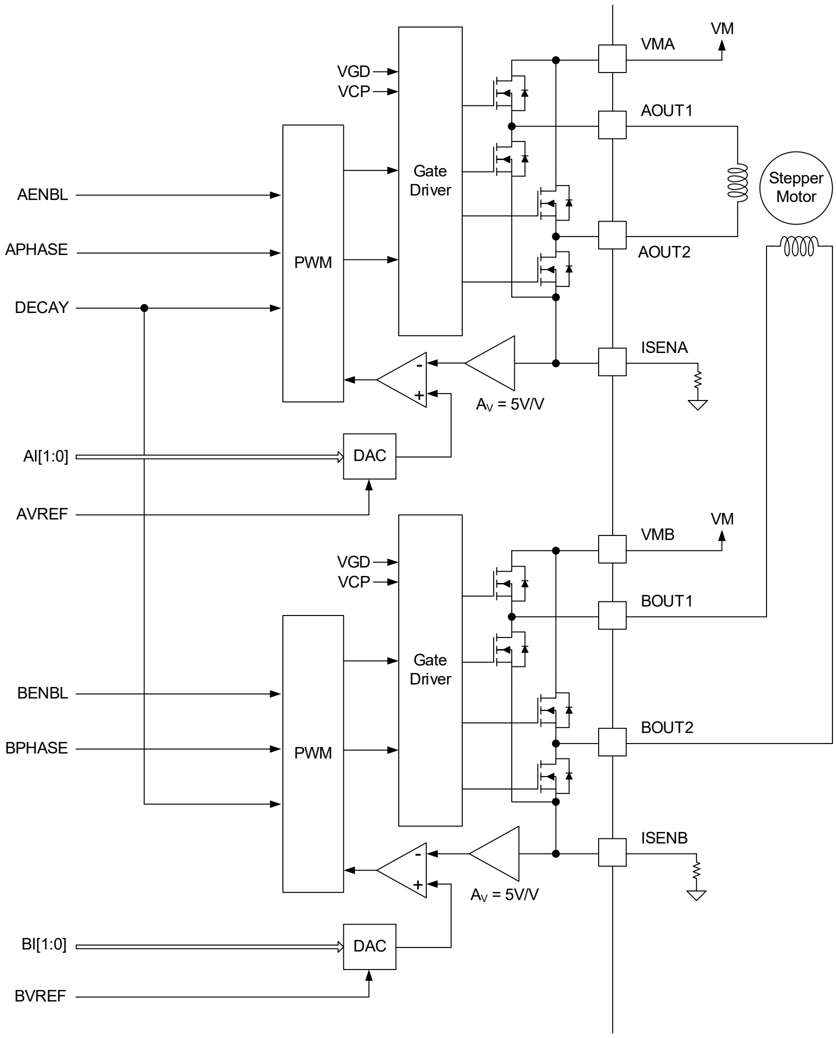


Figure 2. The SGM42613 PWM Motor Control Circuit

DETAILED DESCRIPTION (continued)

Bridge Control

The xENBL active high enable inputs turn the H-bridge outputs on and the xPHASE inputs control the H-bridge current direction as shown in Table 1.

Table 1. H-Bridge Control Logic with xENBL/xPHASE Inputs

xENBL	xPHASE	xOUT1	xOUT2
0	X	Z	Z
1	1	H	L
1	0	L	H

Current Regulation

With each PWM pulse, the winding current rises at a rate determined by the winding inductance and the H-bridge DC voltage (V_M/L). When the current reaches the chopping threshold (path S1 in Figure 3), the pulse is terminated and current will decay until the next PWM cycle, as will be explained in the next section.

H-bridge current is sensed by a shunt resistor connected from the ISENx pin to GND. The sensed voltage is multiplied by A_V = 5V/V and then it is compared with the chopping threshold as reference. This threshold is generated by multiplying, the xVREF input voltage to one of the four scale factors: 0 (or disabled), 38%, 71% or 100% (full-scale). The scale is set by the xI1 and xI0 digital inputs through a 2-bit DAC. Therefore, the full-scale chopping current is given by:

$$xI_{CHOP} = \frac{xV_{REF}}{5 \times R_{SENSE}} \quad (1)$$

For example, with a 3.3V reference and R_{SENSE} = 0.5Ω, the full-scale current is 3.3V/(5 × 0.5Ω) = 1.32A.

Note that when both I0 and I1 inputs are high, there is no current and the H-bridge is disabled. In the previous example, if xI1, xI0 = 00, the full-scale chopping current is 1.32A. For xI1, xI0 = 01 and 10, it is 0.937A and 0.502A, respectively. For xI1, xI0 = 11, the H-bridge will be disabled (no current).

Table 2. H-Bridge Current Scaling with DAC Digital Inputs

xI1	xI0	Relative to I_{FS} Current (% Full-Scale Chopping Current)
1	1	0% (Bridge Disabled)
1	0	38%
0	1	71%
0	0	100% (Full-Scale)

Decay Modes

After the current reaches to the chopping threshold and the PWM pulse is terminated, the H-bridge switch states will change depending on the selected decay mode (fast or slow).

In the fast decay mode, after reaching the threshold, the state of all switches are reversed to apply negative voltage to the winding and force the current to ramp down to zero (path S2 in Figure 3). The H-bridge is disabled (all switched off) just before the winding current reaches zero to avoid current reversal. Fast decay is selected by applying a high logic to the DECAY input.

In the slow decay mode, after the threshold is reached, the upper switch is turned off and both lower switches are turned on to apply zero voltage on the winding and reduce current (path S0 in Figure 3). The current ramp down slope is slower in this case. Winding current will circulate in the lower switches during slow decay. Slow decay is selected by applying a logic low to the DECAY input.

The SGM42613 supports a mixed decay mode as well by leaving the DECAY input open (float). In this mode the decay starts in fast mode for a fixed period (33% of the t_{OFF} time) and then changes to slow mode for the rest of the cycle.

DETAILED DESCRIPTION (continued)

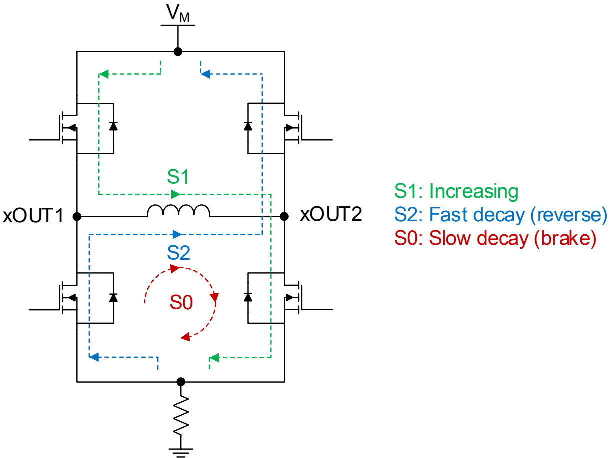


Figure 3. Decay Modes and Current Paths in the H-Bridges

xENBL, nRESET and nSLEEP Inputs

The xENBL is an active high enable input for the bridge x. When xENBL is pulled low, H-bridge will brake for 10ms, then all H-bridge FETs are disabled.

The nRESET is an active low reset input for the internal logic. All other logic inputs are ignored if nRESET is low.

The nSLEEP is an active low input to put the device in low-power (sleep mode) state. In sleep mode, all internal clocks, bridges, charge pump and V3P3OUT regulator are disabled (stopped). Also, all logic inputs are ignored.

When nRESET or nSLEEP is pulled low, H-bridge will brake for 10ms, then all H-bridge FETs are disabled. After removing the sleep mode, a short recovery time (near 1ms) is needed before the driver can go back to full operation mode.

Protection Features

This device is protected against under-voltage, over-current and over-temperature conditions as will be described below.

Over-Current Protection (OCP)

All switches of the H-bridges are current limit and if an over-current is detected on one of them, its gate drive signal is removed. If the current limit persists for a period longer than the OCP time, H-bridge will brake for 10ms, then all H-bridge FETs are disabled and the nFAULT output is pulled low (shutdown). The device will not restart automatically and will be disabled until V_M supply is removed and re-applied or reset through nRESET pin.

Over-current may occur due to an output short to ground, or to V_M rail, or across the motor windings. The OCP is independent of ISENx circuitry and inputs.

Thermal Shutdown (TSD)

The device will shut down if the die temperature exceeds shutdown threshold. H-bridge will brake for 10ms, then both H-bridges will turn off and the nFAULT output will be driven low. Device will recover automatically when the temperature falls below the TSD hysteresis window.

Under-Voltage Lockout (UVLO)

If the VM pin voltage falls below the under-voltage lockout threshold, all internal circuits will be disabled and the internal logic will be reset. Operation resumes when V_M exceeds the UVLO rising threshold.

APPLICATION INFORMATION

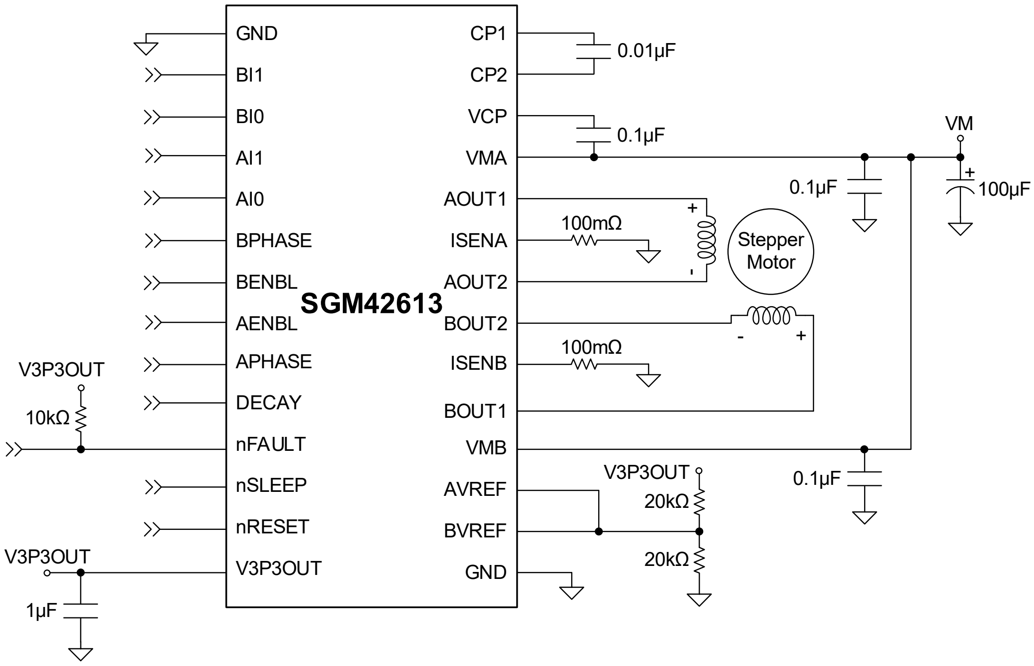


Figure 4. SGM42613 Typical Application Schematic with Stepper Motors

The application of the SGM42613 for bipolar stepper motor control is explained in this section.

Requirements

Design requirement examples are provided in Table 3.

Table 3. Design Parameter Example Values

Design Parameter	Name	Value
Supply Voltage	V_M	24V
Motor Winding Resistance	R_L	3.9Ω
Motor Winding Inductance	I_L	2.9mH
Sense Resistor Value	R_{SENSE}	100mΩ
Target Full-Scale Current	I_{FS}	2A

Design Procedure

Current Regulation Setting

The full-scale current (I_{FS}) in a stepper motor is the maximum current that can be delivered to each winding. The I_{FS} depends on the xVREF voltage and the R_{SENSE} resistor. While stepping, I_{FS} is the actual chopping threshold (I_{TRIP}) for the maximum current in each step. As discussed for Equation (1) with the sensing gain of Av = 5V/V for the SGM42613, the full-scale current can be calculated as:

$$I_{FS}(A) = \frac{xVREF(V)}{A_V \times R_{SENSE}(\Omega)} = \frac{xVREF(V)}{5 \times R_{SENSE}(\Omega)} \quad (2)$$

So, with R_{SENSE} = 100mΩ, to get I_{FS} = 2A, the xVREF voltage must be set to 1V.

Decay Modes

The SGM42613 supports three different decay modes: slow decay, fast decay, and mixed decay. The winding currents are regulated by fixed frequency PWM. Each PWM pulse continues until the winding current reaches the chopping threshold (I_{TRIP}), and then one of the three decay modes starts and continues until the next PWM pulse.

The blanking time (t_{BLANK}) limits the lowest width of the PWM drive pulse. Note that due to ignoring the I_{TRIP} current during the t_{BLANK} period, a current overshoot may occur and cause over-current protection.

APPLICATION INFORMATION (continued)

Designing the Sense Resistor

For a better performance, consider the following criteria for selecting the sense resistor:

- Choose a surface-mount and low inductance shunt.
- Consider resistor power rating ($I_{RMS}^2 \times R_{SENSE}$), and ambient temperature derating.
- Place this resistor close to the ISENx pin to avoid stray inductances and voltage overshoots.

For example, if the motor RMS current is 2A and with R_{SENSE} = 100mΩ, the resistor loss is 0.4W. For 3A, it will increase significantly to 0.9W.

Usually, resistors rated power is given at a specific ambient temperature such as room temperature. A derating curve is also provided for higher ambient temperatures, caused by other system elements. It is advised to check the actual temperature of the resistor and other power components in the final system and make sure they are operating within their rated operating range.

For lower cost and to reduce inductance and also for better distribution of the heat, several standard resistors can be placed in parallel between the sense and GND pins rather than using a large shunt resistor.

Power Supply

The SGM42613 operating supply voltage (V_M) is from 8.2V to 36V. Connect VMA and VMB pins together and to the motor power supply. Place two separate 0.1μF decoupling ceramic capacitors as close as possible to these pins and device GND. Additional bulk capacitors are also required and should be placed close to the device. The bulk capacitance is selected based on the application needs as described in the next section.

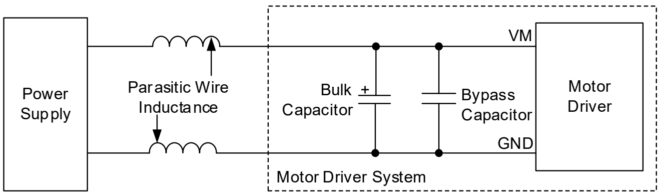


Figure 5. External Supply Connection

Bulk Capacitors

Consider the following factors to design the bulk capacitor:

- Power supply type (impedance, current limit, ripple, etc.)
- Maximum acceptable V_M voltage ripple
- Parasitic inductance of the supply wiring
- Type of the motor (stepper)
- Motor start-up current requirements
- Motor braking method

As a rule, try to minimize the parasitic inductance of the supply to motor connections. High inductance limits the response time when a rapid current change is needed and causes large voltage spikes. Similarly, if the bulk capacitance is not large enough, sharp changes in the motor current result in large voltage drops (or increased voltage when motor brakes). The bulk capacitance must be large enough to limit switching and stepping ripples in the acceptable range for proper operation. A final test on the design is recommended to verify or adjust the selected bulk capacitance value.

REVISION HISTORY

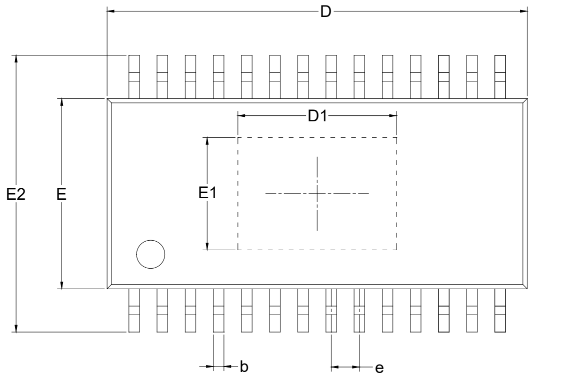
NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

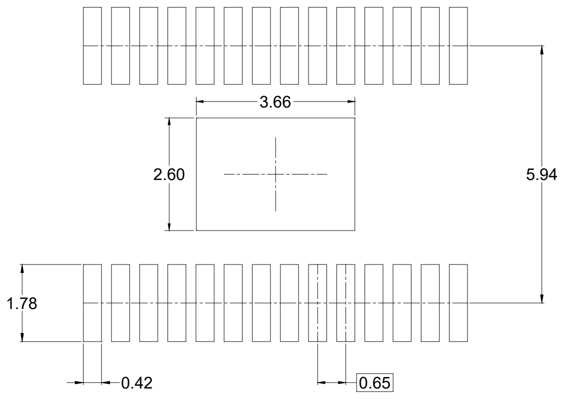
DECEMBER 2022 – REV.A to REV.A.1	Page
Updated Absolute Maximum Ratings section	2
Updated Package Outline Dimensions section	13

Changes from Original (SEPTEMBER 2022) to REV.A	Page
Changed from product preview to production data	All

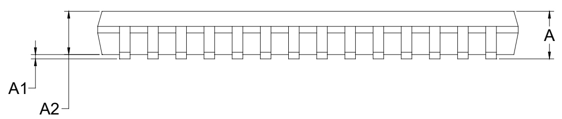
PACKAGE OUTLINE DIMENSIONS

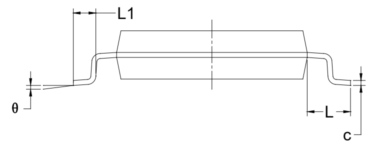
TSSOP-28 (Exposed Pad)





RECOMMENDED LAND PATTERN (Unit: mm)



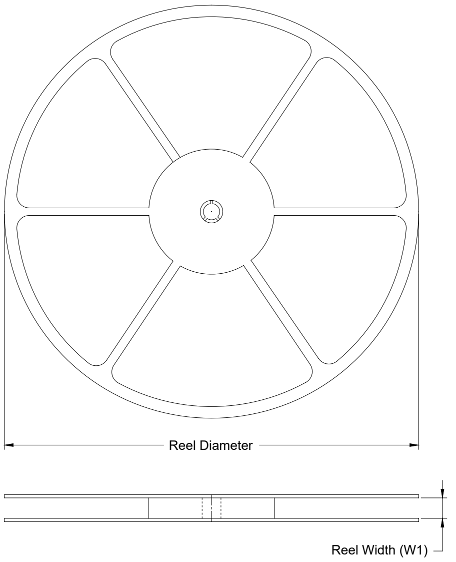


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A		1.200		0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	9.600	9.800	0.378	0.386
D1	3.460	3.860	0.136	0.152
E	4.300	4.500	0.169	0.177
E1	2.400	2.800	0.094	0.110
E2	6.200	6.600	0.244	0.260
e	0.650 BSC		0.026 BSC	
L	1.000 BSC		0.039 BSC	
L1	0.450	0.750	0.018	0.030
θ	0°	8°	0°	8°

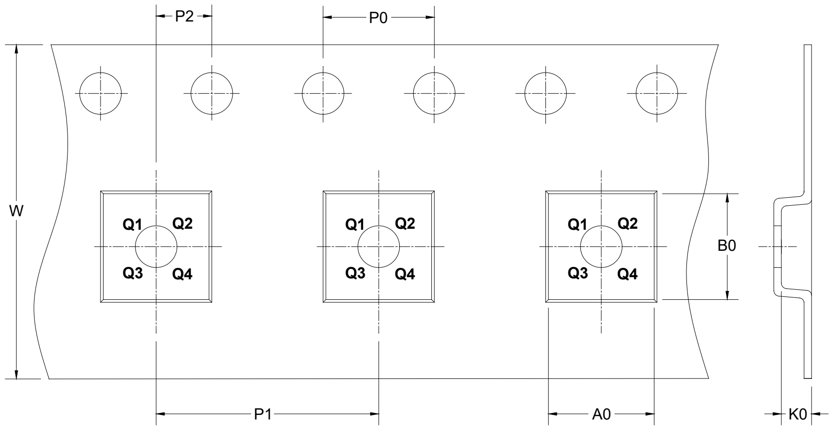
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-153.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

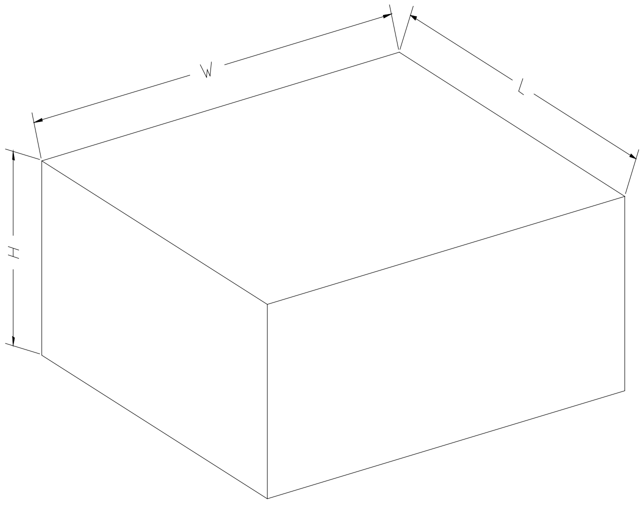
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TSSOP-28 (Exposed Pad)	13″	16.4	6.80	10.25	1.60	4.0	8.0	2.0	16.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

DD0002